

# “Black Star” or Astrophysical Black Hole?

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**Abstract.** Recently wide publicity has been given to a claim by T. Vachaspati that “black holes do not exist”, that the objects known as black holes in astrophysics should rather be called “black stars” and they not only do not have event horizons but actually can be the source of spectacular gamma ray bursts. In this short essay (no flimsier than the original preprint where these extravagant claims appeared) I demonstrate that these ill-considered claims are clearly wrong. Yet they present a good occasion to reflect on some well known but little discussed conceptual difficulties which arise when applying relativistic terminology in an astrophysical context.

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## 1. A QUESTION EVERY PHYSICS STUDENT ASKS (AND VERY FEW GET AN ANSWER...)

I remember when, as an undergraduate physics student, I was first confronted with the peculiar properties of black holes. Like many other students, I was particularly bothered by the concept that while a falling object can reach the event horizon in a finite proper time, the same will take infinitely long when measured by an external observer (coordinate time). By the same argument, the formation of the black hole in gravitational collapse would also take an infinitely long time for the observer. So how can we talk about black holes having been formed in the collapse of dying stars?

When I asked my professor, he suggested that I should think about it this way: the event horizon has already formed but, owing to the strong time dilatation, we have no knowledge of it yet, nor will we until the end of time. Which, incidentally, is the very reason why nothing beyond the horizon can ever be seen, i.e. why the horizon is a horizon and why the black hole is a black hole.

This reply is ultimately based on the intuitive notion that proper time is, in some sense, indeed the “proper” time, i.e. that the time difference of two events (such as the beginning of gravitational collapse and the formation of the event horizon) should be measured in a frame where they occur at the same place. Indeed, there is a time honoured tradition in astronomy to apply *light-time correction* to observations when giving ephemerides. In this vein, talking about astrophysical black holes follows from the application of the principle of light-time correction, which in this case happens to be infinite.

While this kind of “light-time argument” is the most common way astronomers deal with the above conceptual problem, there is clearly something unsatisfactory about it.

General relativity is based on the principle that the laws of physics are the same in all frames of reference, so no frame is more legitimate than the other. Yet the above argument is based on the assumption that proper time is, somehow, the “real” time and coordinate time is just some appearance. But then, it is exactly appearances we are dealing with in astronomy —so if we make such an arbitrary distinction between the two frames, would it not be more plausible to base our terminology on what is measured in coordinate time?

While it is true that in the observer’s frame every single particle of the collapsing star will in principle remain observable until the end of time, this is a purely hypothetical observability. The reality is that any radiation emitted from collapsing star’s material, suspended just above the Schwarzschild radius, will be gravitationally redshifted+dilatated into oblivion. Thus, from the observer’s point of view, the object behaves just like an already formed black hole: the collapsed material has disappeared from sight for good, while the behavior of anything that is far enough from the would-be horizon to be observable is governed by the Schwarzschild (or Kerr) metric.

The ultimate justification of talking about “astrophysical black holes” lies in this empirical indistinguishability of the objects from *bona fide* black holes.

## **2. AN EXTRAVAGANT CLAIM (AND WHY IT’S OBVIOUSLY WRONG...)**

It is this indistinguishability that is challenged by Vachaspati [1] who claims that the collision of two “astrophysical black holes” may result in readily observable —indeed, spectacular— effects. If this were true, it would indeed invalidate the use of the term “black hole” for these astrophysical objects. Vachaspati proposes “black star” instead.

By order of magnitude estimates he shows that the energy released in the collision of two “black stars” is comparable to that of gamma ray bursts, and it should be radiated in the high energy electromagnetic regime. If so, this could be a possible mechanism to produce gamma ray bursts.

What he inexplicably seems to forget, however, is that

(a) The time it takes for two colliding “black stars”, shrunken arbitrarily close to the Schwarzschild radii, to actually get in contact is arbitrarily long in coordinate time, for the same well known reasons as for a test particle falling into the hole. Thus, currently observed gamma ray bursts (or any astronomical phenomenon) cannot be attributed to this.

(b) The estimate of the emitted power is based on the collision timescale in *proper time*, so even if such a gamma ray burst were produced in the vicinity of the Schwarzschild radius, it would be gravitationally redshifted+dilatated into oblivion, as any other kind of radiation.

### 3. A SLIGHTLY LESS EXTRAVAGANT OTHER CLAIM (AND WHY IT'S IRRELEVANT TO ASTROPHYSICS...)

In a related earlier paper, Vachaspati, Stojkovic and Krauss [2] study the radiation of the material collapsing into a black hole in quantum field theory. They find that the infalling material is fully radiated away in what they call “pre-Hawking radiation” before a black hole could form. If true, this would mean that actually *no* black holes that were not present from the start of time could *ever* form in *either* proper or coordinate time. Assuming for a moment that this claim is not based on the same kind of fallacy as the claim about gamma bursts, this claim would have far-reaching consequences e.g. for the attempts to create black holes in colliders.

Nevertheless, even if it were proven correct, its consequences for astrophysics would be rather limited. True, this would imply that a true black hole would not form even in infinite coordinate time, so the light-time correction argument for calling these objects black holes would fail. However, in macroscopic black holes the quantum effects that give rise to Hawking and “pre-Hawking” radiation operate on time scales much longer than the age of the universe, so the observed behavior of astrophysical black holes would not be influenced. And we have already seen that the more fundamental reason for calling these objects black holes is the impossibility of distinguishing them empirically from already formed *bona fide* black holes. This principle is still alive and well, implying that there is no need to drastically change our terminology. For the pedantic, the “astrophysical” qualifier in front of “black hole” should serve as sufficient reminder of the true nature of the objects we are dealing with.

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### REFERENCES

1. T. Vachaspati, arXiv:astro-ph/0706.1203v1
2. T. Vachaspati, D. Stojkovic, and L. M. Krauss, *Phys. Rev. D*, in press; arXiv:gr-qc/0609024v3 (2007).